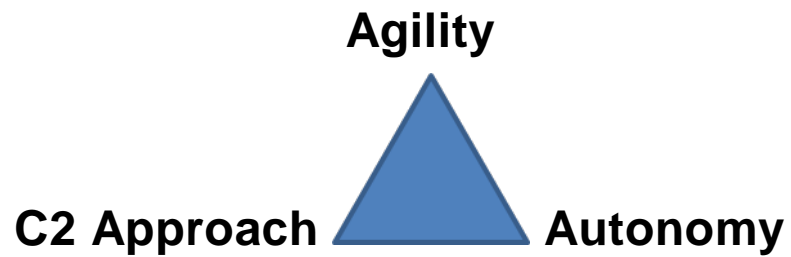




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April 2015

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Log: H 15-000491  
IDA Document NS D-5499

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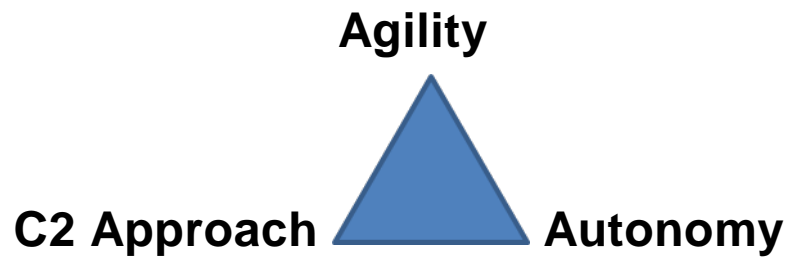
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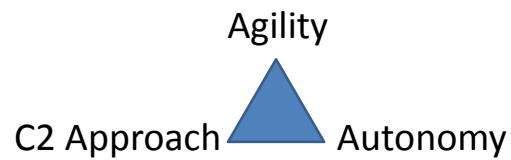
# INSTITUTE FOR DEFENSE ANALYSES

IDA NS D-5499



**David S. Alberts**  
**Kathy Conley**





*Concepts and Challenges*

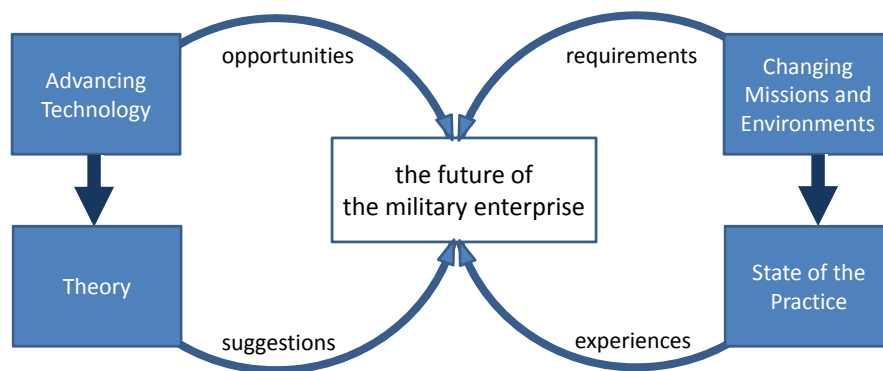
David S Alberts  
Kathy Conley  
Institute for Defense Analyses

prepared for  
DSB Summer Study on Autonomy  
April 30, 2015

## Presentation Overview

- Review the evolution of command and control concepts and approaches in response to
  - Desire to take advantage of the power of information age technologies
  - Need to respond to the complexities of 21<sup>st</sup> mission challenges
- Suggest that recent developments in C2 theory and concepts provide an appropriate conceptual framework for thinking about how to design autonomous systems and integrate them into operations

## Do we need to change our approach to C2?



3

## Yes—We Need New C2 Approaches

- Legacy approaches to C2 are insufficient because:
  - They cannot satisfy critical mission requirements
  - They can not fully leverage increasingly automated / autonomous capabilities
- We have an opportunity to do C2 differently because:
  - The economics of C2-related technologies have changed significantly
  - They continue to change at a rapid pace
- We now understand how to deliberately manipulate C2
  - But, new approaches to C2 will not arise naturally
  - Long-held assumptions impede the design, development, and adoption of new approaches

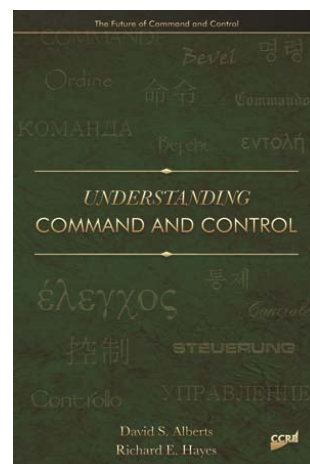
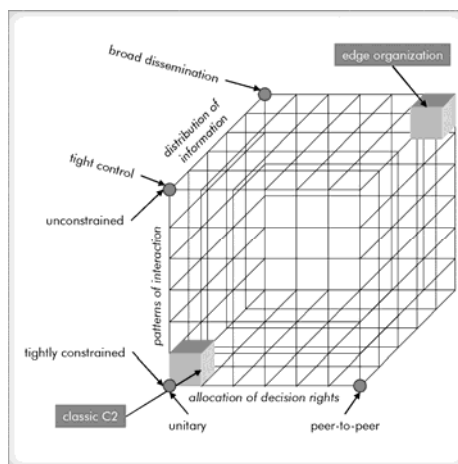
4

## C2 Approach Space

- There are a great many possible approaches to accomplishing the functions that we associate with Command and Control.
- Developing the “option space” for Command and Control requires that major differences between possible approaches are identified.
  - Centralized v. Decentralized
  - Fixed Vertical Stovepipes v. Dynamic Task Organized
  - Limited information dissemination (need to know) v. broad dissemination (need to share)
- These difference are reflected in the dimensions of the C2 Approach Space (options available)
  - Allocation of Decision Rights (within an entity or to the collective)
  - Patterns of Interaction
  - Distribution of Information

5

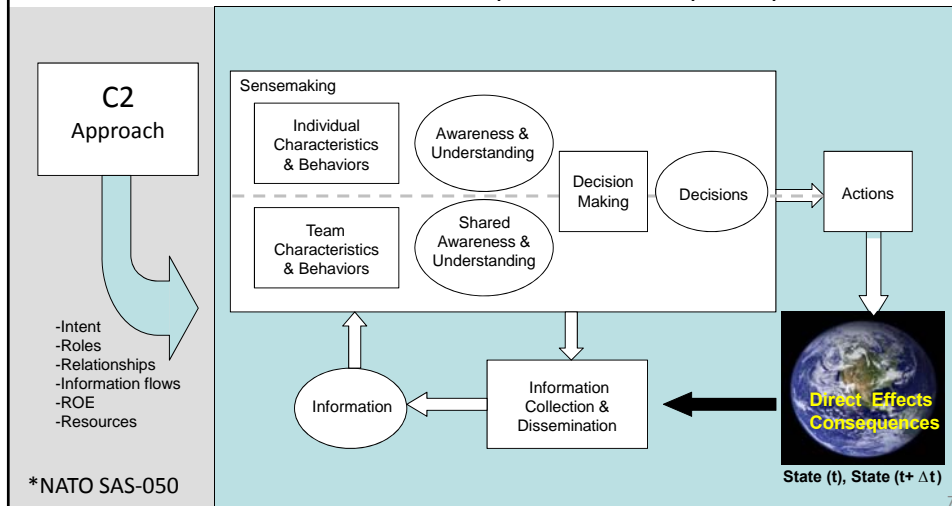
## The C2 Approach Space



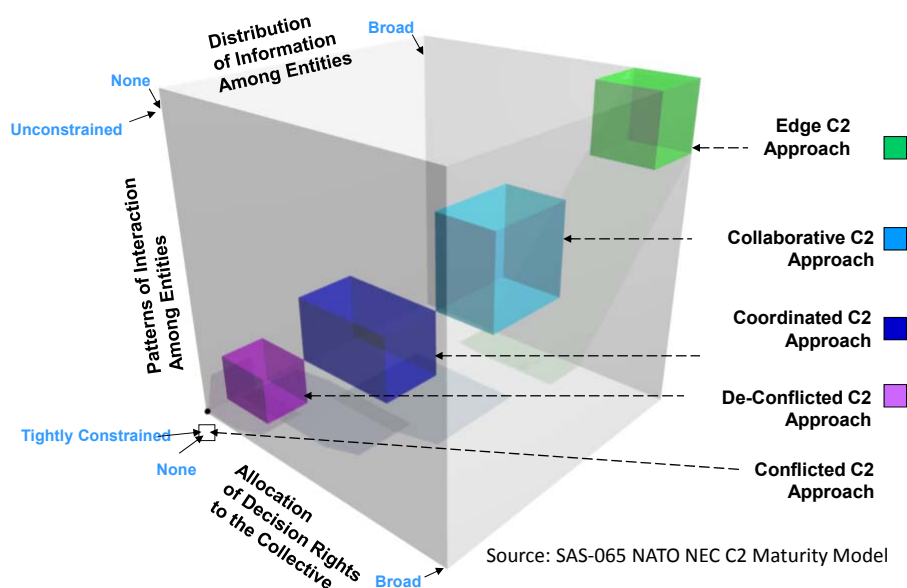
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## NATO C2 Conceptual Reference Model\*

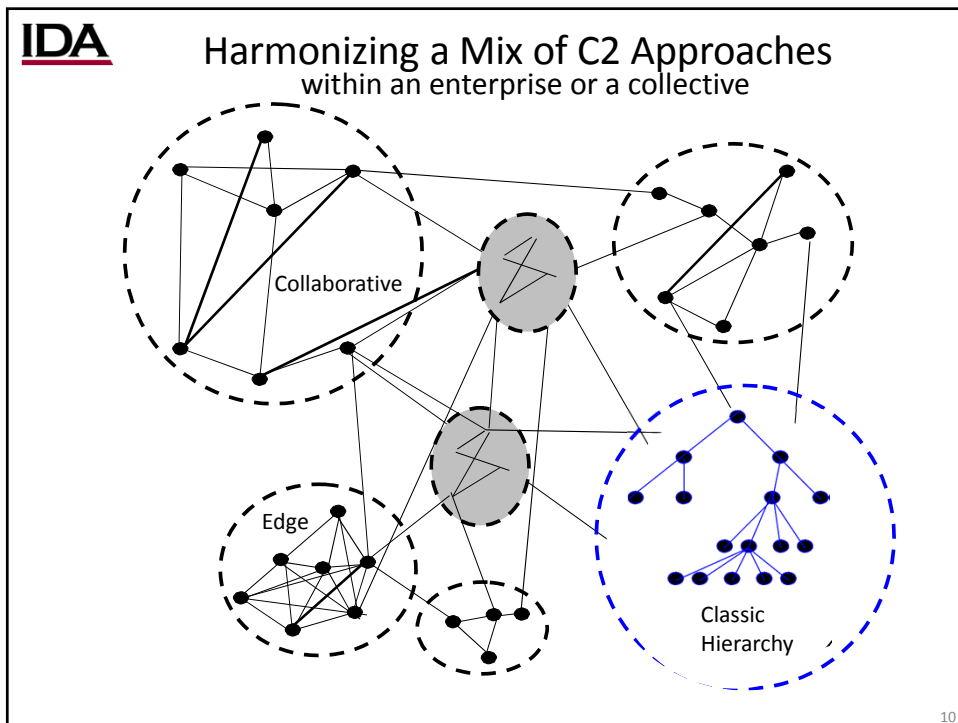
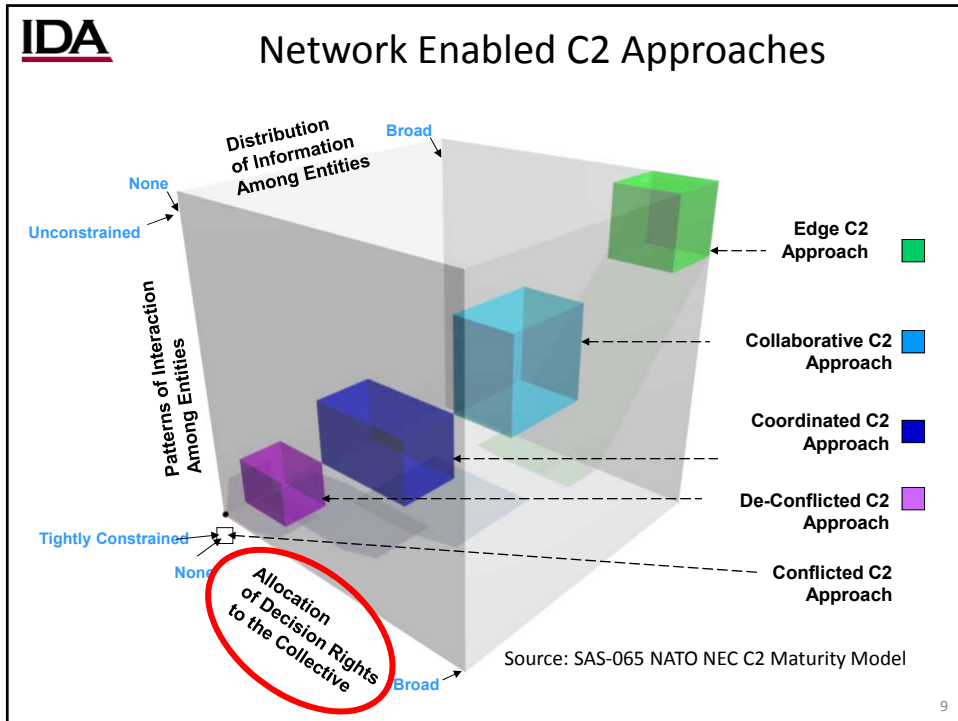
An approach to C2 determines the nature of the endeavor, the way individuals and organizations relate to one another, and determines the information positions of all participants



## Network Enabled C2 Approaches



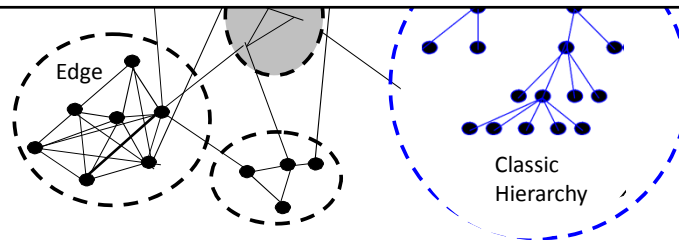




## Harmonizing a Mix of C2 Approaches within an enterprise or a collective

How does the approach to C2 practiced by one entity (unit or system) affect the ability of the Enterprise to function?

- How does it affect the distribution of information?
- How does it change the patterns of interactions?
- What happens when an entity does not cede any decision rights to the enterprise?



11

## C2 Shapes and Employs

C2 both **shapes** the force and **employs** it

Shaping is C2 at the Enterprise level

- Creates the "Force"
- Determines Capabilities over time



**Shaping Determines**

**What is Possible**

**Employing Determines  
the What and How of  
an Operation**



Employing is C2 at the Mission level

- Establishes Intent
- Creates/Instantiates a Mission Capability Package at time  $t$  for purpose  $p$

**C2 creates the initial conditions for an operation**

**and dynamically adjusts**

12

## Complex Endeavors and Enterprises

- Complex Endeavors are characterized by multidimensional, inter-dependent effects spaces and profound levels of uncertainty
- Complex Endeavors involve Complex Enterprises, a heterogeneous collection of networked military and civilian partners and systems that each can function with varying degrees of autonomy (a multi-genre, composite network)
- There will, of necessity, need to be multiple approaches to C2 and the processes that support C2
- Operations, to be effective, will require developing synergies between and among the actions taken by individual entities and collections of entities (human and 'machine')
- Complexity, with its inherent lack of predictability greatly increases the need for and value of Agility

13

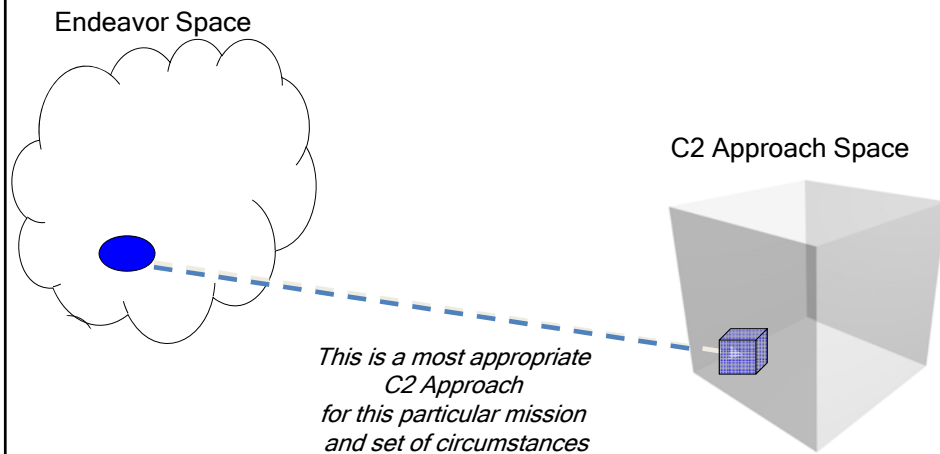
## Agility

- Agility is the capability to successfully effect, cope with, and/or exploit changes in missions and circumstances.
- Its enablers include:
  - Responsiveness
  - Versatility
  - Flexibility
  - Resilience
  - Adaptability
  - Innovativeness
- Agility is a necessary response to growing mission complexity and uncertainty and have expressed a desire for more agile forces
- Agility is applicable to individuals, organizations, material, systems, and collections of these
- Agility is much too important to be left to chance

14

## C2 Agility

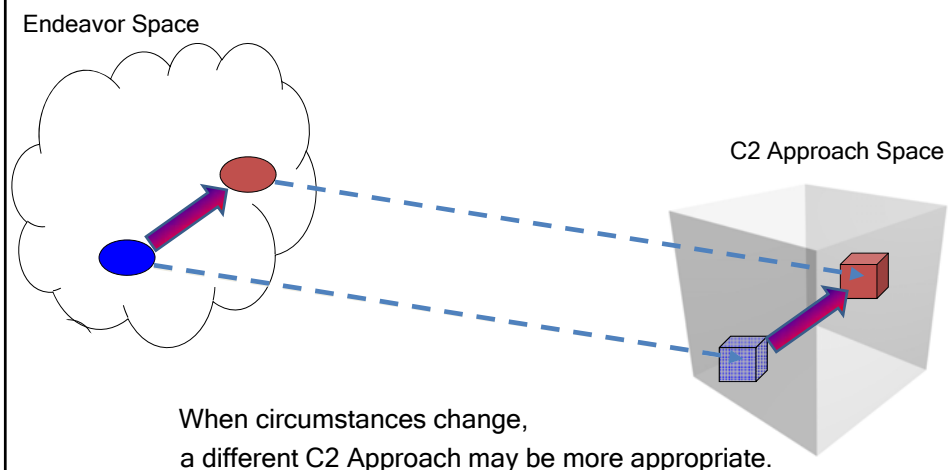
### Step 1: Adopt the Appropriate Approach



15

## C2 Agility

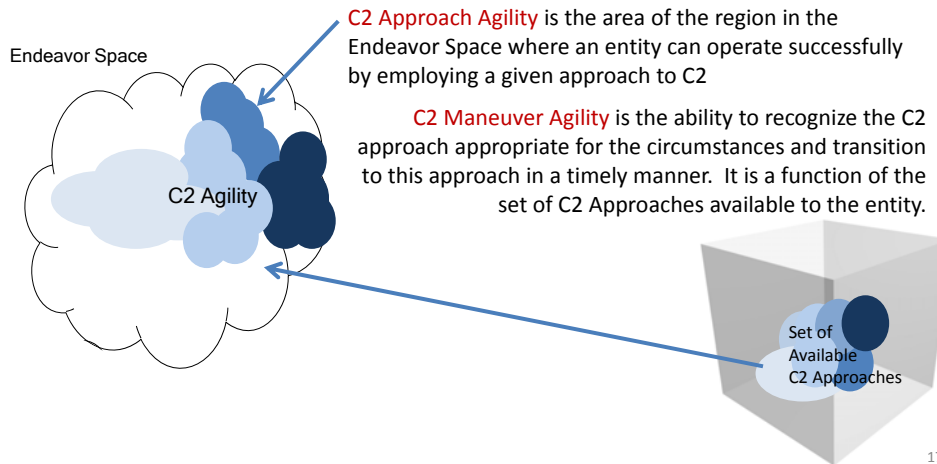
### Step 2: Adapt C2 Approach as Circumstances Change



16

## C2 Agility

- $C2\text{ Agility} = f(C2\text{ Approach Agility}, C2\text{ Maneuver Agility})$



17

## Traditional v Agile C2

	Traditional C2	Agile C2
<b>Approach</b>	one way	set of options
<b>Decision Rights</b>	limited delegation of decision rights	as appropriate
<b>Interactions</b>	prescribed interactions	tailored
<b>Information Dissemination</b>	limited – need to know	access as appropriate - need to share
<b>System Requirements</b>	point to point support established processes	network support emergent processes

18

## Traditional v Agile C2

Which approach is more appropriate for autonomous forces?

	Traditional C2	Agile C2
<b>Approach</b>	one way	set of options
<b>Decision Rights</b>	limited delegation of decision rights	as appropriate
<b>Interactions</b>	prescribed interactions	tailored
<b>Information Dissemination</b>	limited – need to know	access as appropriate - need to share
<b>System Requirements</b>	point to point support established processes	network support emergent processes

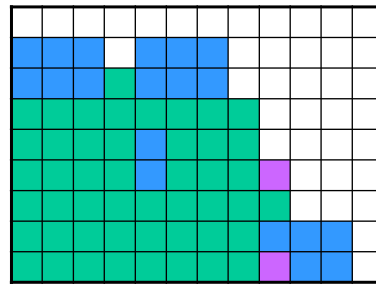
19

## C2 Research and Analysis Findings

- No single approach to accomplishing the functions associated with C2 fits all missions or situations whether for a single entity or a collection of interdependent entities
- Thus, the most network enabled approach is not always the most appropriate
- Rather, the most appropriate approach will be a function of the endeavor and the prevailing condition and circumstances
- The manifested C2 Approach can be significantly difference from the intended C2 Approach due to conditions and circumstances
- Therefore,
  - Entities will need to be able to appropriately employ more than one C2 approach and monitor it
  - Collections of interdependent entities will need to harmonize their approaches to C2

20

## Comparative Agility Map for Organization-Approach options



Organization Approach Options

- Edge
- Collaborative
- Coordinated
- De-conflicted

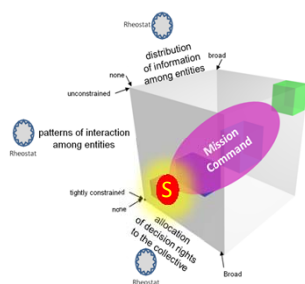
Endeavor Space

with varying conditions of signal to noise  
and with varying requirements  
for shared situation awareness and response time

Source: Alberts, D.S. The Agility Imperative, 2010 Part V: Agility Experiments

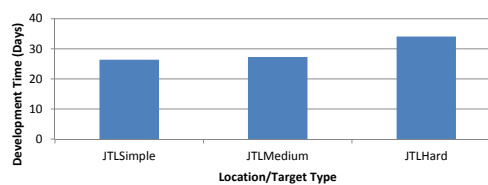
21

## Simulation Results—Base C2 Approach

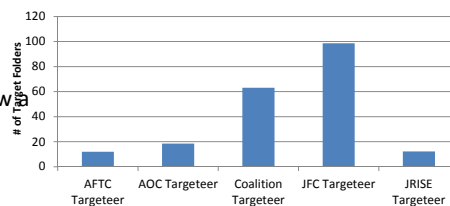


**S** Start-point - currently:  
Target Folders are distributed for  
development through e-mail (fixed  
allocation) and the decision boards follow  
specific timetable (no targets getting  
vetted/validated outside this process)

Average Joint Targeting List (JTL) Target  
Development Time

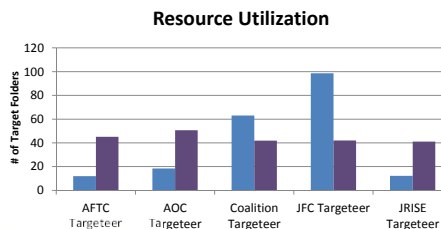
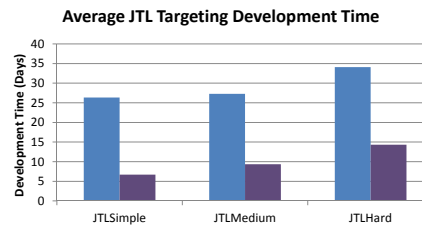
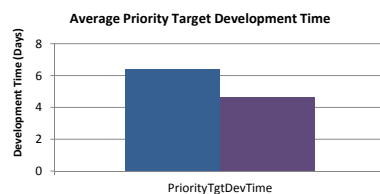
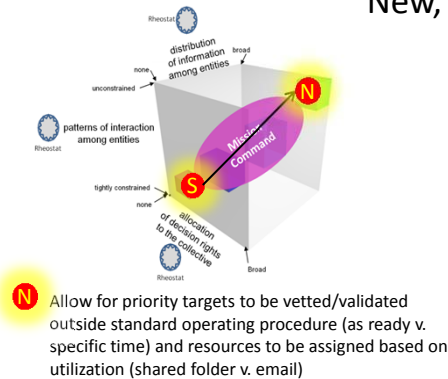


Resource Utilization



22

## New, Co-Evolved C2 Approach



Overall JTL & Priority Target Development Time Decreases and Resource Utilization Levels out

23

**IDA**

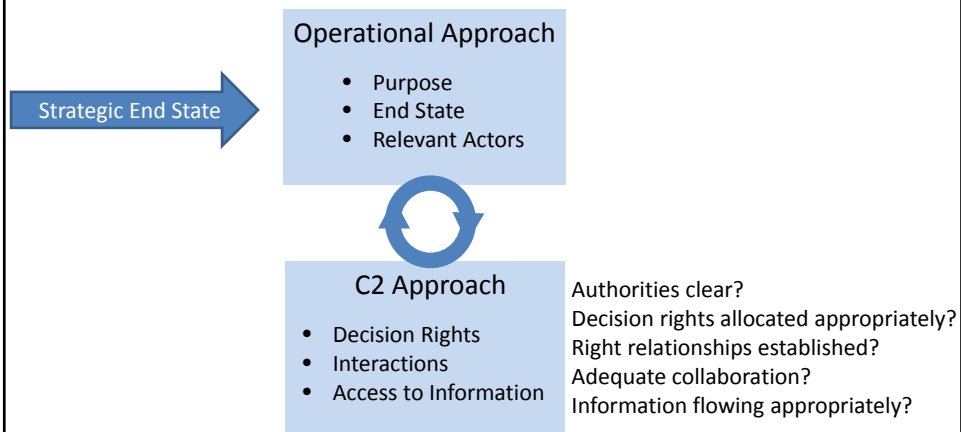
## C2, Automation and Autonomy

- Automation involves the delegation of selected decision rights to 'agents' that operate within specified rules of engagement (doctrine)
- Autonomy is the delegation of decision rights within the context of command intent
  - Applies to humans, robots, and software agents
  - Can command intent be dynamic?
- Both can be thought of in terms of the C2 Approach Space
  - Their accesses to information
  - How they interact with other automated entities and/or human (human in the loop v. human on the loop )
- Both automated and autonomous entities can possess varying degrees of Agility

24



## C2 Questions Relevant to Autonomy



Source: "C2 by Design," DoD CCRP (2015) p. 27

25

Thanks for your attention.

Questions? Comments?

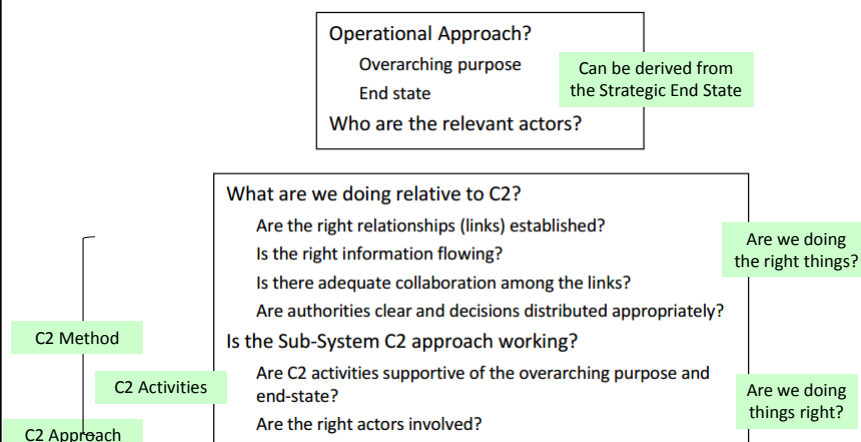
26

## Assessing the C2 Approach<sup>13</sup>

	Macro Assessment	Macro Red Teaming
Are we doing the right things?	<p>What is the intended C2 approach?</p> <ul style="list-style-type: none"> <li>Metric: The C2 plan has observable elements</li> </ul> <p>Is the C2 approach as implemented what was intended?</p> <ul style="list-style-type: none"> <li>Metric: Actual C2 structures and activities are observable</li> </ul> <p>Is the C2 approach working? Is it enabling both the operational approach as a whole and its individual lines of effort?</p> <ul style="list-style-type: none"> <li>Metric: Bottom-up reporting, not just on linkages but, more importantly, on whether the information flows, collaborations, and decision authorities are healthy and enabling both timely decisions and action. Reporting would be on friendly C2 information requirements</li> </ul>	<p>What has changed or could change in the operational environment that will impact the C2 approach?</p> <p>Example categories:</p> <ul style="list-style-type: none"> <li>Mission change or mission creep</li> <li>Organization (own or external)</li> <li>Actors (more or fewer)</li> <li>LOE (progress or lack of progress)</li> <li>Changes in the enemy situation (positive or negative) or in factors beyond the commander's control that work for against mission accomplishment (such as weather and terrain)</li> <li>Communications security compromises</li> </ul> <p>What are the most important changes to address first?</p> <ul style="list-style-type: none"> <li>Consider risk and urgency?</li> </ul> <p>How will the most important changes impact the C2 approach?</p> <ul style="list-style-type: none"> <li>What adjustment would be required?</li> </ul> <p>What indicators would illuminate change in the operational environment and how can they be monitored?</p> <ul style="list-style-type: none"> <li>How can this be implemented? What are the commander's C2 information requirements</li> </ul>
Are we doing things right?		<p>→ "CC2IR"</p>

<sup>13</sup> CCRP, "C2 by Design," pg 26.

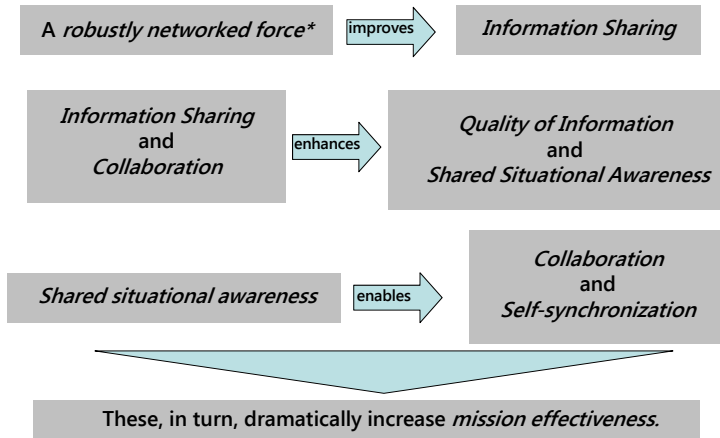
## C2 Questions Relevant to Autonomy<sup>14</sup>



<sup>14</sup> CCRP, "C2 by Design," pg 27.

## Tenets of NCW

NCW provides opportunities to employ new C2 approaches and warfighting concepts

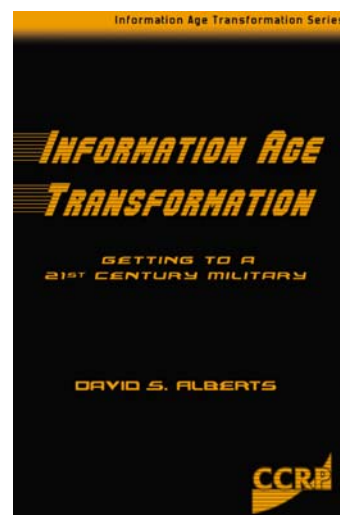


\*"Networking the Force" entails much more than providing connectivity among force components. It involves the development of distributed collaboration processes designed to ensure that all pertinent available information is shared and that all appropriate assets can be brought to bear ... Network Centric Warfare Report to the Congress March 2001

29

## C2 and NCW

- "NCW, in its most mature form, involves profound changes in the role of a commander and the relationships between a commander, a commander's staff, subordinates, and superiors."

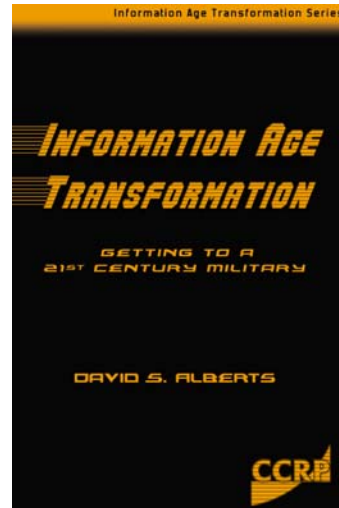


30

## C2 and NCW

### Automation / Autonomy

- “~~NCW~~ in its most mature form, involves profound changes in the role of a commander and the relationships between a commander, a commander’s staff, subordinates, and superiors.”



31

## Evidence Continues to Accumulate a few examples

- NCW book provided examples of how leveraging shared awareness results in increased combat power [http://www.dodccrp.org/files/Alberts\\_NCW.pdf](http://www.dodccrp.org/files/Alberts_NCW.pdf)
- NATO SAS-065 reports on cases studies and experiments that address the link between various C2 approaches and mission success [http://www.dodccrp.org/files/N2C2M2\\_web\\_optimized.pdf](http://www.dodccrp.org/files/N2C2M2_web_optimized.pdf)
- NATO SAS-085 provides results from case studies and from an analysis of data from a variety of experiments that support the need for more network enabled and agile C2 <http://www.dodccrp.org/html4/sas-085.html>
- C2 by Design contains supporting evidence [http://www.dodccrp.org/files/c2agility\\_handbook.pdf](http://www.dodccrp.org/files/c2agility_handbook.pdf)
- C2-Re-envisioned: The Future of the Enterprise provides an analysis of C2 failures and successes <http://www.crcpress.com/product/isbn/9781466595804>
- NATO SAS-104 is currently working to help member nations and NATO organizations create awareness of C2 Agility and is gathering evidence of its mission impacts <http://www.dodccrp-test.org/sas-104>

32

## Challenges

- Make the leap from thinking about the 'network' as ICT to thinking in terms of a multi-genre composite network that needs to be designed and operated in an integrated fashion
- Move beyond optimizing C2 for a given mission or scenario to developing more agile C2 Approaches and learning to maneuver in the C2 Approach Space
- Forge the partnerships necessary to create a transformation ecosystem linking research, analysis, experimentation, concept development and doctrine, education and training, acquisition, force development, and lessons learned
- Undertake real experimentation and exercises that are not 'scripted' but that are properly instrumented, create unfamiliar situations, and stress people, processes and systems


33

## Challenges: The Science of C2

- Recognize that the performance and behaviors of communications, information, and C2 networks and their embedded automated processes are inter-dependent and can not be studied in isolation
- Recognize that these networks are subject to damage and a variety of stresses that can cascade within individual networks and across network boundaries
- Appreciate that C2 is not an end unto itself but needs to be considered in mission and enterprise terms
- Recognize that automated processes constitute a delegation of decision rights and the need to find an appropriate balance
- The tenets of NCW apply to the research community every bit as much as they do to the operational community

34



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1. REPORT DATE (DD-MM-YY) xx-4- 2015		2. REPORT TYPE Final		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE  Agility C2 Approach  Autonomy				5a. CONTRACT NO. HQ0034-14-D-0001	
				5b. GRANT NO.	
				5c. PROGRAM ELEMENT NO(S).	
6. AUTHOR(S) David S. Alberts, Kathy Conley				5d. PROJECT NO.	
				5e. TASK NO. SFRDOH	
				5f. WORK UNIT NO.	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Institute for Defense Analyses 4850 Mark Center Drive Alexandria, VA 22311-1882				8. PERFORMING ORGANIZATION REPORT NO. IDA NS Document D-5499 H 15-000491	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Institute for Defense Analyses 4850 Mark Center Drive Alexandria, VA 22311-1882				10. SPONSOR'S / MONITOR'S ACRONYM(S) IDA	
				11. SPONSOR'S / MONITOR'S REPORT NO(S).	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT  Autonomy is, in fact, an approach to command and control (C2) as it involves a delegation of decision rights to the autonomous entity and with it, either implicitly or explicitly, access to information. Agility has been shown to be a function of the approach to C2. Thus, these three concepts are intimately related. As a result of the inter-relationships that exist, the conceptual framework developed by the DoD Command and Control Research Program with its international partners over the years provides a systematic way to think about and assess autonomy options..					
15. SUBJECT TERMS C2, Agility, Autonomy					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT  UU	18. NO. OF PAGES  17	19a. NAME OF RESPONSIBLE PERSON David S. Alberts
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19b. TELEPHONE NUMBER (Include Area Code) 703-845-2411

